September 2023

Systems Thinking Applied to Higher Education Curricula Development

Reza Rahdar
Embry-Riddle Aeronautical University, rahdarr@erau.edu

Mark London
Embry-Riddle Aeronautical University, londonm@erau.edu

Yuetong Lin
Embry-Riddle Aeronautical University, liny4@erau.edu

Hong Jiang
Embry-Riddle Aeronautical University, jiangh@erau.edu

33rd Annual INCOSE international symposium
hybrid event
Honolulu, HI, USA
July 15 - 20, 2023

Systems Thinking Applied to Higher Education Curricula Development

Mark London
School of Engineering, Embry-Riddle Aeronautical University Worldwide
One Aerospace Blvd, Daytona Beach, 32114-3966, FL, United States
londonm@erau.edu

Reza Rahdar
School of Engineering, Embry-Riddle Aeronautical University Worldwide
One Aerospace Blvd, Daytona Beach, 32114-3966, FL, United States
rrahdar@erau.edu

Hong Jiang
School of Engineering, Embry-Riddle Aeronautical University Worldwide
One Aerospace Blvd, Daytona Beach, 32114-3966, FL, United States
jiangh@erau.edu

Yuetong Lin
School of Engineering, Embry-Riddle Aeronautical University Worldwide
One Aerospace Blvd, Daytona Beach, 32114-3966, FL, United States
liny4@erau.edu

Abstract. Systems Thinking (ST) is a general and yet nebulous term that describes an approach to understanding and working with complexity in the real world. ST seeks to evaluate different behaviors of individual system elements when they operate in isolation as opposed to when they are integrated as part of a larger system and placed within a particular operating environment. The education environment consists of multiple systems with different digital content, learning goals/outcomes that serve different stakeholders including teachers, learners, and administrators. The inherent complexity and interaction among these various educational system elements and functions make this environment a worthy candidate for consideration within the ST context. In this paper we examine the application of ST principles to higher education. Specifically, our study suggests that systems thinking methods and concepts can promote improved outcomes in curricula development with a positive impact on student learning.

INTRODUCTION

Systems Thinking (ST) is a general yet nebulous term that describes an approach to understanding and working with complexity in the real world. ST seeks to evaluate different behaviors of individual system elements when they operate in isolation as opposed to when they are integrated as part of a larger system and placed within a particular operating environment. This term covers a range of formal methodologies and various approaches to perform the component and system level

evaluation, including aspects of system network theory (Newman 2018), mathematical graph theory (Diestel 2010; Gross & Yellen 2006), and probabilistic system behavior (Khisty, Mohammadi & Amekudzi 2012). Systems thinking, as a distinct discipline from Systems Engineering, evolved incrementally alongside specific "paradigm shifts" demarcating discrete and substantive changes in systems science and system modeling capabilities such as discrete mathematical modeling, graph theory algorithms, computational power increases, and system knowledge management (Kejriwal, Knoblock & Szekely 2021).

We can trace the origin of systems thinking to the classical Greek period. Pre-Socratic philosophers such as Empedocles (mid-fifth century B.C.) of the Pythagorean philosophical school developed a particular metaphysical perspective that suggested all matter is composed of four elements: earth, air, fire, and water (Ruddick, Clark & Clarke 1945). Leucippus and Democritus (early fourth century B.C.) further refined this idea and propounded an atomistic theory of matter in which everything is reducible to discrete and indivisible Atomos (from which we get the English word "atom") (Clark 1997). Later in the Greek philosophical development, Aristotle, in his Metaphysics, summarized the idea of holism in the statement that "the whole is more than the sum of its parts." Derek Cabrera, however, suggests the origin of the idea of systems thinking arose not from the ancient Greek philosophers but from Lao Tzu in the Tao Te Ching around 2600 years ago (Cabrera, Cabrera & Lobdell 2008).

These representative examples from ancient Eastern and early Western philosophy share one common characteristic in their respective metaphysical approaches. Empedocles, Leucippus, Democritus, and Aristotle all claim (albeit in diverse ways) that the real world of tangible objects developed from various configurations of more fundamental particles or elements.

Moreover, the preceding thinkers asserted that the fundamental elements possess unique attributes in themselves but that when these elements are placed in combination and integrated with other elements, the original individual elements lose some of their unique characteristics as they support the attributes of the higher-level entity of which they become a part. Thus, they each held to a nascent form of systems thinking in which the attributes and characteristics of lower-level elements change as they integrate into high-level and more complex entities.

To bring this foundation idea into more modern times, the formal idea of reductionism (i.e., the idea that artefacts or phenomena are described in terms of other simpler phenomena or artefacts) was first introduced by Renee Descartes in Part V of his "Discourses on Method" of 1637 (Ruddick, Clark & Clarke 1945). Von Bertalanffy (von Bertalanffy, Hofkirchner & Rousseau 2015) formulated modern systems thinking with his introduction of contemporary concepts of system theory. More advanced understanding and application of systems thinking has since emerged as a multi-disciplinary reaction to previous versions of reductionistic theory. Consequently, Systems thinking—even with its inclusion of reductionistic attributes—is now used across different domains and disciplines including social sciences, engineering, management, organizational leadership, education, computer science and medicine.

As we seek to pull and apply these principles of thought to contemporary times, we see that the higher education environment consists of multiple systems with functions including teachers, learners, administrators, digital content, and learning goals/outcomes. The inherent complexity and interaction among these various educational system elements and functions makes this system it a worthy candidate for consideration within a ST context. More specifically, ST considerations for

higher education suggest a particularly fruitful application is found in the curricula development aspects of the higher education system in a corresponding focus on improving curricula flexibility and student outcomes.

However, external factors have impacts on the education system, especially the effect of cross-boundary external influences that can adversely impact particular educational elements. For instance, major government policy and financial limitations will thwart a logical, coherent approach to educational issues. Education system components should work together and identify any adversity outside the system. Having a good understanding of external and internal factors and how these factors impact the education system will foster higher education improvement.

In this paper we contribute to the application of ST in the higher education system by a review of ST principles and their application to higher education curricula development. Following a summary of contemporary concerns with higher education curricula development and systems thinking principal concepts, we present a simple iterative systems-thinking based model that provides for a holistic consideration of system influences and factors across the external and internal educational environment space as well as a feedback mechanism for problem identification, evaluation, and solution implementation. Selected proposed systems thinking benefits are applied to higher education curricula development, which are followed by a conclusion and suggestions for future research in this field.

CURRENT LIMITATIONS IN HIGHER EDUCATION

The history of education is well rooted in the existence of the original socialization of humans. From the ancient Middle East (about 3000 BCE, Egypt, and Mesopotamia) to the North China (about 2000-1500 BCE), from European Renaissance to post industry revolution time, education emphasized the transmission of culture, values, and accumulated knowledge of a society. For thousands of years, education was performed in non-formal and informal means via both one-on-one student-tutor arrangements (especially among elites and the higher classes in a given society) and teacher-students relationship (e.g., Plato's Academy, Aristotle's Lyceum, Islamic Madrasa). The current western educational system paradigm has its root in the comprehensive school system reform pioneered by Wolfgang Ratke and John Amos Comenius and is heavily influenced by the mid-19th century Prussian educational structure.

Despite the long history of human educational programs and approaches, the contemporary educational environment presents novel concerns not readily addressed by historical educational methodology. According to (World Economic Forum 2022) , the four biggest challenges faced by the current higher education system are: (1) increasing need for life-long learning in a non-linear world, (2) evolving needs and expectations of the "student-consumer", (3) emerging technologies and business models, and (4) a "skills over degrees" model preference among younger generations as well as some employment field. Furthermore, Banathy (Banathy 1999) suggested five reasons for the failure of current approaches in making the proper transition to the contemporary educational environment: (1) adoption of a piecemeal or incremental, transition approach, (2) failure to integrate solution ideas, (3) absence of a discipline-by-discipline study of education processes within each discipline, (4) implementation of a reductionist orientation, (5) intentionally staying within the boundaries of the existing system (i.e., not thinking "out of the box"). A cursory review of these transition and process limitations suggests that much of the problem stems from an

intentional and lingering focus on changing or modifying specific elements or components of the education system rather than considering and adopting changes that address the interconnections and integration among educational system elements and sub-components. In short, modern educational systems improperly emphasize the "parts" of the educational system instead of seeing the system from a "whole" perspective including assessment of interactions among system elements and system components. This emphasis of the components of the educational system at the expense of evaluating the complete system is the inverse of key systems thinking principles. In the next section we consider these principles and suggest additional ideas within the context of the higher education system.

SYSTEMS THINKING PRINCIPLES

Systems thinking covers a broad swath of concepts, some of which are of a general and "common-sense" nature whereas others more pointedly focus on application within systems engineering context. Seven commonly accepted principles of systems thinking are:

- Analyze system from the perspective of the entire system, and not as a generic assemblage of individual components or sub-system elements.
- Identify system boundaries as framing the extent of the system under consideration as well as clarifying the interface between external and internal factors upon the system.
- Analyze interactions among various combinations of system elements and sub- system components, especially as such interactions can produce unforeseen and unpredicted behavior of the overall system.
- Consider influences and factors upon a system and its components, especially the effect of cross-boundary external influences that can adversely impact particular system elements.
- Evaluate internal system feedback mechanisms (whether of a positive or negative nature) that can adversely affect the performance of the system even in the absence of clear external or internal factors or stressors upon the system.
- Review and mitigate identified problems with a given system in such a manner that sufficiently employs systems thinking principles.
- Reflect upon the extent and type of complexity resident within a given system in- carnation and how such complexity can complicate system analysis across the previously listed systems thinking principles.

These principles may be fruitfully employed in a variety of systems including healthcare, human behavior, as well as more complex formally engineered systems. In the environment of the "system" of higher education curricula development, systems thinking principles can be applied in several ways. Nevertheless, not all these principles are explicitly considered in this paper, but the previous list represents a broad outline of basic concepts and principles.

A central focus of systems thinking is understanding the attributes of a complete system as related to the combined attributes of the component elements. Nevertheless, there is another aspect of systems thinking that emphasizes the analysis and evaluation of problems within a system, and

consideration of a logical and analysis-based process to understand the interrelated nature of issues that can arise within complex systems. Considering this latter concern within the context of higher education, we can leverage the insights from (Cuff & Forstag 2018) to develop a process to evaluate issues within curricula development as shown in Figure 1.

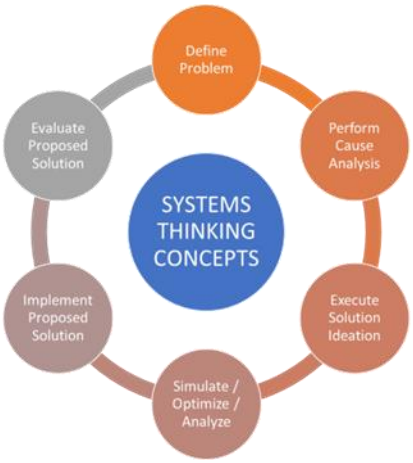


Figure 1. Systems thinking concepts for higher education development and problem identification, analysis, and solution implementation (adapted from (Cuff & Forstag 2018))

Admittedly the concepts of this problem identification and evaluation process are of a general nature. Nevertheless, we will see in the following section that there is a connection of this process to the higher education environment that can provide proper feedback to education system to improve curricula development in a progressive and iterative fashion. The next section considers these systems thinking principles and applies them to the system of higher education curricula development.

LITERATURE REVIEW of SYSTEMS THINKING APPLICATIONS

In the prior section we addressed and discussed several systems thinking principles. System thinking allows us to see how things interrelate with others (Senge 1990), and to analyze and understand complex system behaviors. Systems thinking applications span across different domains such as social science, mining industry (Cooke 2003), aviation systems (Hustache, Gibellini & De Matos 2001), energy power systems (Kadoya et al. 2005), decision-making (Ford & Lyneis 2020), and curriculum design (Schoepen et al. 2022). Additional areas in which systems thinking has been recently employed include numerous areas within engineering and health professional organization (McDonnell, Heffernan & Faulkner 2004), business and manufacturing industry behaviors (Gonçalves n.d.), banking system, human performance (Chu 2006), supply chain management (Killingsworth, Speciale & Martin 2011), civil engineering applications such as effects of project personnel changes, rework, conflict management (Ng, Peña-Mora & Tamaki 2007), road maintenance budgeting (Bjornsson, de la Garza & Nasir 2000), and project management (Morrison 2007). Nevertheless, the use of these principles within the field of higher education curricula development is very limited. This is the emphasis of this paper.

Today, higher education sits within a society in flux and the traditional education incumbents face increasingly demanding situations. Universities must reevaluate and determine the roles their institutions should assume in the future (Morrison 2007). As Orr (Orr 2004) notes, ". . . if certain precautions are not taken, higher education may equip people to become more effective vandals

of the earth." This concern that higher education trains the mind but does not equip the student to live and act in a moral manner within society is not a new revelation. The comments of Presbyterian theologian and professor J. Gresham Machen when he appeared before a Joint Congressional Committee in 1926 to testify against the installment of a proposed Federal Department of Education are perhaps a suitable precursor to Orr's comments where Machen noted, "If you give the bureaucrats the children, you might as well give them everything else as well" (Machen & Robbins 1995). Moreover, Mauricio Macri (former president of Argentina) in G20 summit in 2018, "the future of work is a race between technology and education" (Accenture 2018). His comment indicates that there is an urgent need to transform degree programs, courses, and curricula in general, to satisfy the needs of modern learners and keep pace with the evolving workforce (EDUCASE 2020). Indeed, curricula development becomes vital as higher education institutions are striving to design learning experiences that relate to and satisfy the modern-day tech-savvy students.

SYSTEMS THINKING APPLICATIONS IN HIGHER EDUCATION

As we noted above, systems thinking is an ability to think about the system as a whole; to address the important system level issues; to recognize that there are latent properties in systems; and to judge and balance that enables one to juggle all the various considerations and make a proper choice (ESD 2007). A systems thinking approach, therefore, produces an ability to see the whole beyond the parts and seeing the parts in the context of the whole especially as we consider schools in general, and higher education in particular, as an artifact worthy of evaluation with a systems thinking model. Below are specific reasons to incorporate systems thinking into higher education:

- *ST looks at systems as a whole rather than individual parts in isolation.* This ST principle enables practitioners to consider the higher education environment by accounting for the myriad influences and factors that can affect student performance and outcomes.

- *ST focuses on process instead of content.* This consideration provides for a broader application of ST principles across the education system in a somewhat course content-agnostic manner, thereby encouraging standardization of processes and methods across the curricula and across academic departments.

- *ST searches for potential causes and the dynamic factors that might play as key component (i.e., feedback loops).* The analysis of such feedback mechanisms is an important consideration in identifying factors and influences that can influence processes and student outcomes in unpredictable or potentially unmanageable ways.

- *ST thinks in "big picture" rather than thinking on one problem.* This is similar to the first item above, but with a focus on problem identification and solution evaluation rather than system structure. That is, as ST practitioners identify problems with a given higher education system their solution identification and integration should be done with consideration of the holistic environment and external/internal factors around a given system's boundary.

- *ST understands how system components work together and transcend the boundaries of the system.* Identification of system component interactions and mutual influences, as well as how the system elements both influence the system environment outside the system boundaries and are influenced by the environment outside of the system boundary, provide a broad perspective from which to evaluate system operation and effects of weak or strong

influences. Within a higher education environment, this suggestion speaks to the need of ST practitioners to implement broad view of those factors that present secondary or tertiary influences on the education at a given institution (e.g., those external factors identified earlier in Figure 2).

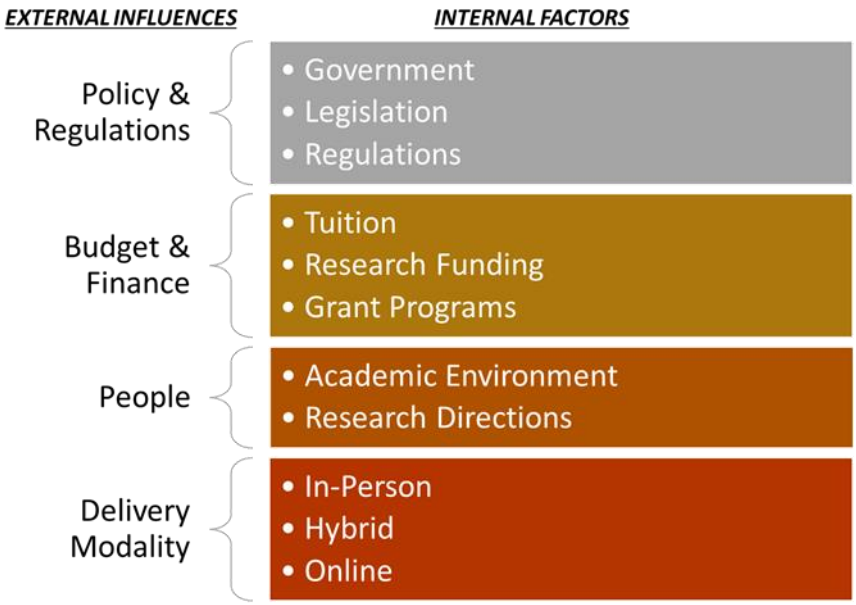


Figure 2. Broad definition of external influences and internal factors related to a systems thinking approach for higher education curriculum development

- *ST offers a valuable approach for instructors working to build student engagement.* By leveraging ST principles in developing the curricula in a general sense, these same principles may be implemented within specific course context in such a manner that encourages student critical thinking by developing project examples that requires students to analyze problems from a broader standpoint.

- *ST approaches help leaders organize schools by harnessing their assets.* Proper use of ST principles will foster efficiency and flexibility in curricula development and implementation processes and methods. These improvements will enable higher education institutions to make more profitable use of their available resources.

- *ST goes hand-in-hand with interdisciplinary teaching and learning.* Application of ST principles provides a flexible and balanced approach to curricula development that is especially useful for those academic institutions that provide interdisciplinary fields of study and multiple modalities of student learning. Viewing the curricula development process from a holistic perspective, for instance, will better support a balance of student learning opportunities across learning modalities (in-person, hybrid, online, etc.) to ensure consistency of pedagogical quality and student outcomes.

- *ST and socio-technical systems (STS) promotes the understanding of the education ecosystem in the university environment.* ST using STS approaches like applied organizational change and Cognitive Work Analysis can build conceptual model of the education system

for understanding the interactions and relationship between people, technology, processes and organization (Dhukaram et al. 2018)

- *ST helps faculty training to improve the quality of education.* Faculty training courses provided by universities are short-term refreshers focusing on instructional skills and adaptation to existing curricular organization. With ST, a formative process can be established with pedagogical practice at the core and integrating faculty's personal strength to orient the training process to collaborative learning (Astaíza-Martínez, Mazorco-Salas & Castillo-Bohórquez 2021).

Dissanayake (Dissanayake 2021) described higher education institutions as an open system that consists of major inputs needed to run the education institution, major outputs, and system process to convert inputs into outputs. This open system interacts with the surrounding environment through varied factors that impact higher education institutions. Specific key elements include social factors, technological factors, economic factors, and political factors, legal and ethical factors.

Von Bertalanffy (von Bertalanffy, Hofkirchner & Rousseau 2015), one of the pioneers of systems thinking, distinguished between closed systems, for which no material may enter or leave, and open systems, such as living systems, for which material may enter or leave and thus a change in its components takes place continuously. Meadows (Meadows 2008) notes that systems have elements, interconnections, and purpose. Systems are characterized by three important concepts: hierarchy, homeostasis, and purposiveness. Curricula development is a part of the education open system, which also shares the same inputs of the higher education system. The major inputs needed to develop curricula are at the organizational level, human level (e.g., department leaders, instructors/professors/educators, course designers, students, staff, and other personnel), and technology and equipment level. Previous research indicated that there is a strong link between student achievement and associated educational system (Selvik, B. & Moen 2022). Developing curriculum in the higher education system is complex and comprises key relationships among different elements in order to achieve learning outcomes. Among all components of systems thinking, becoming a learning organization is crucial to being successful in this process. Organizational leadership should realize how complex the whole university is. They should be able to take necessary steps to grow and improve organization through increasing technical sophistication during the curricula development (Dhukaram et al. 2018). Technical sophistication includes hardware, software, and any technical advancement.

During the course development, an effective leader should be able to identify the area of improvement; provide support to this course; motivate a further development (Selvik, B. & Moen 2022; Levin et al. 2010) mentioned that leaders should promote partnership aligning support and resources and adapt to changing context in the process. Leaders ensure coordination and integration of service across campus, faculty, staff, and administrators (Jenkins 2007). Shukla (Shukla 2018) stated that educational leaders must comprise three valuable practices of systems thinking; (1) identify appropriate stakeholders and uncover values of group, (2) design framework for change and model feedback loops, and (3) engage all stakeholders and promote coordination of network align support and resources. Besides leaders, instructors/professors/educators, and/or course designers should also be able to apply systems thinking to see a big picture during the curriculum development. Instructors and professors should consider both instructional-focus and learner-focus

approaches (Banathy 1999). Additionally, feedback and assessment from students in the previous courses also play a significant role.

Dissanayake (Dissanayake 2021) argued that aligning support and resources through community and collaboration should be applied to course development. Different perspectives from other knowledgeable partners will support such collaborative thinking during this process. Higher education institutions have collaborated with industry subject matter experts (SMEs) to design and teach courses. With collaborative partnerships, instructors and professors can gain large-scale connections with the "real-world" scenarios.

Integration of emerging technology is critical towards curriculum development through a systems thinking view. With modern technology, eLearning or online learning is prevalent, especially during COVID-19. Stakeholders involved in the curriculum development should accommodate diversity and rapid changing technology to integrate in the system thinking process. Organizational leaders should take technical sophistication into consideration and keep up to date technology. This is particularly true during the development of engineering curriculum.

However, successful curriculum development can only take place if there is a supportive enabling environment (Ndaruhutse, Jones & Riggall 2019). As a result, the related stakeholders of curriculum development should not only look at higher education, but the surrounding system. They should understand major policy constraints and financial limitations. For example, policy stakeholders as the main initiators of curriculum development should play a role in promoting the system thinking process. Additionally, the overall budget available for curricula development also plays a key influence.

APPROACH TO APPLY SYSTEMS THINKING TO HIGHER EDUCATION CURRICULUM DEVELOPMENT

One way to represent higher education curriculum development is to consider the interrelationships and interactions among a range of factors and influences that affect the persons and institutions seeking to develop such curricula. Figure 2 below shows a representative set of external influences (those outside of the educational institution) and internal factors (those within the educational institution) that can impact the curriculum development process.

The consideration of these influences and factors forms the basis of treating education curriculum development as a complex system and, therefore, one suitable for treatment within a systems-thinking framework. The improvement of quality involves the design of an educational system that not only optimizes the relationship among the elements but also between the educational system and its environment. In general, this means designing a system that is more open, organic, pluralistic, and complex, for instance the example provided by (Banathy 1999). Figure 3 below presents a representative example of a complex yet holistic higher education curriculum development system that not only addresses external factors and internal influences on that system but also provides for problem identification and an iterative process for evaluating such problems and implementing solutions within the broader scope of the system boundaries.

In Figure 3 we see an integration and feedback mechanism of the educational curriculum development external influences and internal factors with the systems thinking problem evaluation and

assessment process, the synthesis of which forms a powerful approach to improving educational curriculum within a holistic systems thinking context.

The inclusion of the broad set of external influences and external factors (left-hand side of the figure) enables the curriculum management team to give a proper consideration to the interrelationships and impact among these elements and better identify issues that are resolved using the identified systems-thinking problem solution process (right-hand side of the figure). The top process link ("curricula development problem" blue arrow) and bottom process link ("solution implementation & assessment" blue arrow) form the components of the problem identification and process solution feedback loop back to the educational system itself. We further note as an aside that the presence of system feedback loops is one of the identifying characteristics of systems thinking approach as discussed by (Meadows 2008). System feedback mechanisms, along with other selected systems thinking principles, are discussed in the next section as we consider benefits of applying these principles within a higher education curriculum system domain.

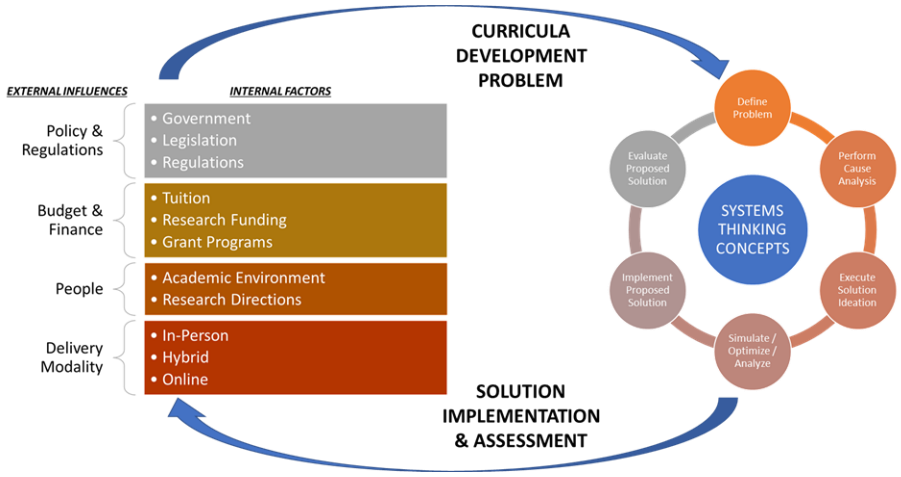


Figure 3. Iterative evaluation process of higher education with systems thinking principles

BENEFITS OF APPLYING SYSTEMS THINKING IN HIGHER EDUCATION

As described above ST is an approach that will able leaders, instructors, and students to see the system as whole and understand its interrelationship and interactions. With a system thinking approach system operators can expand their perspectives in solving complex issues. It can also facilitate organizing the overwhelming possibilities of input, influence, and action. Through collaborative teaching and interdisciplinary curriculum students will be able to see how fields of study demonstrate inter-connectedness and inter-dependence.

The integration of systems thinking into the higher education curriculum development process will offer specific benefits:

- Define Goals and Objectives. Identifying the goals and objectives should be the first step in developing a curriculum. In this process the needs and expectations of students will be understood and considered. Also, it provides a real-time intervention to support student success.

- Support Student Learning Outcomes. The systems thinking approach facilitates curriculum mapping across all the learning environments. It will help identify new and novel opportunities to support student learning outcomes.

- Integrate and Interconnect. The inter-connectedness of different elements of a curriculum will consider different courses, topics, and skills that fit together for the creation of cohesive learning outcomes.

- Implement Feedback Loop. The feedback loops have a significant impact on a curriculum's performance. In this process, students' feedback is incorporated into the curriculum design to improve the learning outcomes.

- Forecast Long Term Prospective. The consideration of long-term impact of decisions is an essential part of ST. Within the higher education curriculum development context, this consideration will enable practitioners to think beyond immediate needs and requirements and focus on long-term student pedagogical needs.

- Examine Larger Societal and Cultural Context. Intentional consideration and evaluation of the context in which the educational system operates will foster curricula design changes to satisfy the needs of students, stakeholders, and society as a whole.

The holistic view of the educational system and consideration of the inter-connectedness of various elements and stakeholders, can help to create a curriculum that promotes student success and contribute to the overall well-being of the educational system and the society.

The systems thinking principles identified above are but a small fraction of those that may be profitably employed in the pursuit of higher education curricula development. As we defined in this paper, by understanding systems and implementing their inherent values, higher education will be able to reform itself. The application of these principles will encourage and foster higher education improvement and will do so in a manner that encourages a proper balance of external and internal factors to the institution itself as well as maintaining a flexible balance of pedagogical methods across learning modalities, and all with a focus on encouraging and improving student learning outcomes. In the final section we will offer a brief conclusion and summary of our preliminary research results and suggest areas for future research and study of this topic.

CONCLUSION

In this paper we focused on the application of ST to curricula development in higher education. We showed that systems thinking methods and concepts can promote improved outcomes in higher education curricula development with a consequent positive impact on student learning and development. Below is a list of critical considerations:

- Systems thinking can be a useful approach to diagnose problems so that solutions that address the needs of a particular education system can be identified.

- Consideration of interrelationships and interactions among factors and influences will affect the students and institutions for curricula development.

- Integration and feedback mechanisms of the educational curricula development external

influences and internal factors with the systems thinking problem evaluation and assessment process form a powerful approach to improving educational curricula but within a holistic systems thinking context.

- Translating systems thinking into the classroom as a problem-solving approach in a manner that creates a new culture within the school system.

We contend that the application of these systems thinking principles to the field of higher education curricula development will produce streamlined administrative processes, simplified curricula development methods, improved faculty performance, and increased student learning across designated course learning outcomes. Future work in this field could include the development of formal case studies that quantitatively assess the impact of systems thinking on higher education curricula development processes, the establishment of a thoroughly-vetted and industry-accepted set of educational curricula criteria external factors and internal influences, and longitudinal assessments of student performance at the K-12, undergraduate, and graduate level as systems thinking principles and concepts are applied to the curricula development process.

References

Accenture 2018, *It's Learning, Just Not As We Know it*, Accenture, Dublin, Ireland.

Astaíza-Martínez, AF, Mazorco-Salas, JE & Castillo-Bohórquez, MI 2021, 'Teacher-researcher training in higher education: A systems thinking approach', vol. 34, no. 2, Springer, pp. 187–201.

Banathy, BH 1999, 'Systems thinking in higher education: learning comes to focus', vol. 16, no. 2, pp. 133–145.

von Bertalanffy, L, Hofkirchner, W & Rousseau, D 2015, *General System Theory: Foundations, Development, Applications*, George Braziller, Incorporated.

Bjornsson, HC, de la Garza, JM & Nasir, MJ 2000, 'A decision support system for road maintenance budget allocation', pp. 702–709.

Cabrera, D, Cabrera, L & Lobdell, C 2008, 'Systems Thinking', vol. 31, pp. 299–310.

Chu, X 2006, *System dynamics modeling for human performance in nuclear power plant operation*, Massachusetts Institute of Technology.

Clark, GL 1997, *Ancient Philosophy*, The Trinity Foundation, Unicoi, TN.

Cooke, DL 2003, 'A system dynamics analysis of the Westray mine disaster', vol. 19, no. 2, Wiley Online Library, pp. 139–166.

Cuff, P & Forstag, EH 2018, 'A Design Thinking, Systems Approach to Well-Being Within Education and Practice', The National Academies Press, Washington, DC, viewed <https://doi.org/10.17226/25151 http://dx.doi.org/10.17226/25151>.

EDUCASE 2020, 'The Horizon Report: Trends', viewed 30 November, 2022, <https://er.educause.edu/articles/2020/3/the-horizon-report-trends>.

ESD 2007, *ESD Terms and Definitions*, 16th ed, Cambridge, MA.

Dhukaram, AV, Sgouropoulou, C, Feldman, G & Amini, A 2018, 'Higher education provision using systems thinking approach - case studies', vol. 43, no. 1, pp. 3–25.

Diestel, R 2010, *Graph Theory*, 4th ed, Springer-Verlag, Heidelberg, GE.

Dissanayake, CK 2021, *General Systems Theory Based Conceptual Framework For Restructuring The Higher Education Institution System*, ASEM, Huntsville, AL.

Ford, DN & Lyneis, JM 2020, 'System dynamics applied to project management: a survey, assessment, and directions for future research', vol. 23, Springer, pp. 285–314.

Gonçalves, P n.d., 'Business Cycle Entrainment: A System Dynamics Approach', Boston, Massachusetts, USA.

Gross, JL & Yellen, J 2006, *Graph theory and its applications*, 2nd ed, Chapman & Hall/CRC, Boca Raton, FL.

Hustache, J-C, Gibellini, M & De Matos, PL 2001, 'A System Dynamics tool for economic performance assessment in air traffic management', Citeseer, pp. 3–7.

Jenkins, D 2007, 'Institutional effectiveness and student success: A study of high- and low-impact community colleges', vol. 31, no. 12, pp. 945–962.

Kadoya, T, Sasaki, T, Ihara, S, LaRose, E, Sanford, M, Graham, AK, Stephens, CA & Eubanks, CK 2005, 'Utilizing system dynamics modeling to examine impact of deregulation on generation capacity growth', vol. 93, no. 11, IEEE, pp. 2060–2069.

Kejriwal, M, Knoblock, CA & Szekely, P 2021, *Knowledge graphs: Fundamentals, techniques, and applications*, MIT Press, Cambridge, MA.

Khisty, CJ, Mohammadi, J & Amekudzi, AA 2012, *Systems Engineering with Economics, Probability, and Statistics*, 2nd ed, J. Ross Pub, Ft. Lauderdale, FL.

Killingsworth, WR, Speciale, SM & Martin, NT 2011, 'Using System Dynamics to Estimate Reductions in Life-Cycle Costs Arising From Investments in Improved Reliability'.

Levin, JS, Cox, EM, Cerven, C & Haberler, Z 2010, 'The Recipe for Promising Practices in Community Colleges', vol. 38, no. 1, pp. 31–58.

Machen, JG & Robbins, J 1995, *Education, Christianity, and the State. The Trinity Foundation*, Unicoi, TN.

McDonnell, G, Heffernan, M & Faulkner, A 2004, 'Using system dynamics to analyse health system performance within the WHO framework', pp. 25–29.

Meadows, DH 2008, *Thinking in Systems: A Primer*, Chelsea Green Publishing, White River Junction, VT.

Morrison, JB 2007, 'Insights from Modeling the Dynamics of Process Improvement', Boston, Massachusetts, USA.

Ndaruhutse, S, Jones, C & Riggall, A 2019, *Why Systems Thinking Is Important for the Education Sector*, Highbridge House, 16-18 Duke Street, Reading Berkshire, England RG1 4RU.

Newman, M 2018, *Networks*, 2nd ed, Oxford University Press, Oxford, England.

Ng, HS, Peña-Mora, F & Tamaki, T 2007, 'Dynamic conflict management in large-scale design and construction projects', vol. 23, no. 2, American Society of Civil Engineers, pp. 52–66.

Orr, D 2004, *Earth in Mind: on education, environment and the human prospect*, 2nd ed, Island Press, Chicago, IL.

Ruddick, M, Clark, GH & Clarke, FTS 1945, *A History of Philosophy*, 2nd ed, F. S. Crofts & Co, New York, NY.

Schoepen, M, Vansteenkiste, E, De Gersem, W & Detand, J 2022, 'Systems thinking and designerly tools for medical device design in engineering curricula', Taylor & Francis, pp. 1–11.

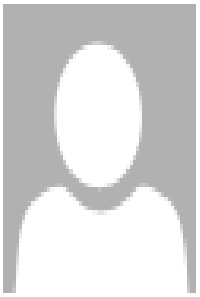
Selvik, JT, B., A, Eirik, & Moen, V 2022, 'Conceptualization and application of a healthcare systems thinking model for an educational system', vol. 47, no. 9, pp. 1872–1889.

Senge, PM 1990, *The fifth discipline : the art and practice of the learning organization*, 1st ed, Doubleday/Currency, New York, NY.

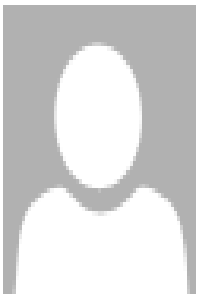
Shukla, D 2018, 'Modeling systems thinking in action among higher education leaders with fuzzy multi-criteria decision making', vol. 13, no. 2, pp. 946–965.

World Economic Forum 2022, 'The 4 biggest challenges to our higher education model - and what to do about them', viewed 22 November, 2022, <https://www.weforum.org/agenda/2019/12/fourth-industrial-revolution-higher-education-challenges/>.

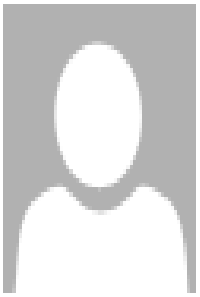
Biography



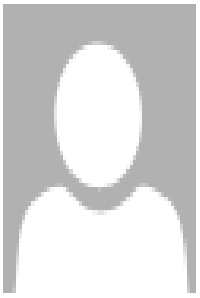
Mark London. Dr. Mark London has earned B.S. and M.S. degrees in Electrical Engineering from the Pennsylvania State University, and Ph.D. in Systems Engineering from The George Washington University. He has more than 20 years of experience in performance evaluation, systems engineering, and test & evaluation of advanced electro-optical, infrared imaging, and laser systems. Dr. London serves as an Adjunct Assistant Professor of Systems Engineering at Embry-Riddle Aeronautical University Worldwide Campus in the College of Aviation. His research interests include the analysis and application of complex multi-layer mathematical network systems, statistical analysis and testing techniques, and application of Bayesian neural networks to develop artificial intelligence problem solutions



Reza Rahdar. Dr. Rahdar currently serves as program chair for the Master of Systems Engineering at the School of Engineering, Embry-Riddle Aeronautical University Worldwide. He began his professional career in the Telecommunication Industries with Nortel Net- works, working for 12 years at positions ranging from research & development engineer, project manager, solution architect, and program manager. Dr. Rahdar's Systems Engineering experience starts with Rockwell Collins in 2006 and then with Raytheon, Bell Helicopter, General Dynamics, and Boeing defense and security systems. His roles and responsibilities ranged from Sr. Systems Engineer to professional systems engineer, and SEIT (Systems Engineering Integration Team) lead



Hong Jiang. Dr. Jiang has been in the engineering field for more than 15 years, working in both academia and industry. She earned a Mechanical Engineering undergraduate degree, a master's degree (MBA in Aviation) from Embry-Riddle Aeronautical University and a second master's degree from the University of Central Florida. In 2013 she earned a Ph.D. degree in Modeling and Simulation from the University of Central Florida. She has applied system engineering life cycle techniques in different aviation systems involving constructing human-centric, equipment-centric, and computer-based models and processes. Her research interests are in Modeling and Simulation applications, machine learning in aviation safety, model-based system engineering, and other aviation safety investigations. Dr. Jiang has served as an Adjunct Assistant professor at the Embry-Riddle Aeronautical University Worldwide campus since 2015. Currently she is a data scientist at the FAA.



Yuetong Lin. Yuetong Lin is an associate professor in the School of Engineering at Embry-Riddle Aeronautical University Worldwide. He received Ph. D. in Systems and Industrial Engineering from the University of Arizona in 2005.